CHAPTER 7

ENVIRONMENTAL MONITORING

7-1. Monitoring Program.

a. General.

(1) Monitoring refers to the overall process of data collection, analysis, and interpretation of either short-term, immediate impacts, or long-term changes over the life of a project. This chapter covers only the coastal aquatic/marine habitat. Readers should refer to EM 1110-2-5026, Chapter 16, if interested in monitoring wetland/terrestrial birds and mammals. Environmental monitoring is usually conducted for several purposes as described below.

(2) Monitoring activities are used to document compliance with standards, control the impacts of construction and operation of projects, evaluate predictions from the planning phase, and guide any necessary remedial work. These predictions are found in the environmental effects section of the project Environmental Impact Statement or environmental assessment, and relate to changes expected to result from the project. Before and after measurements are then compared to establish the accuracy of project predictions. Predictions may be either qualitative, such as a change in fish stomach content, or quantitative, such as a 20 percent reduction in crustacean biomass. Quantitative predictions are of greater value in that threshold levels can be set at which an impact (reduced crustacean biomass) can be deemed significant. If a predicted change does not occur, or if an unexpected changed does occur, either is an indication that the predictor model) is faulty. However, the model may not be totally at fault because of the dynamic system it is attempting to predict. Although the monitored predictions cannot be redone for the existing project or activity being monitored, predictive procedures can be improved for future projects.

(3) Monitoring is also used to determine if project operation meets water quality or other environmental standards. Coordination with other agencies or groups and examination of the Environmental Impact Statement and legal requirements (consent decrees, stipulations, rules and regulations, etc.) will usually reveal areas in which monitoring may be desirable. Monitoring should be limited to parameters that provide information about issues of genuine concern and should produce information (data) that can be compared against environmental quality criteria that exist either in Federal or State regulations or that are negotiated and established for the specific project.

(4) Project operations may also be monitored to assess their effects on cultural resources. This monitoring, if appropriate, should include, but not be limited to, soil erosion and accretion rate in, on, and around cultural resource sites, water table increases or decreases, and vandalism. Vandalism protection devices such as cover, fencing, and masking devices should be evaluated for effectiveness. Such monitoring must be tailored to specific site requirements.

b. Setting Objectives.

(1) The most essential part of an environmental data collection and analysis effort is the establishment of clear and concise objectives. If not done, the net result is often a mass of data that defies rational analysis, an inability to solve the problem for which the data were generated, and a waste of money and effort. Without good objectives, any data collection/analysis effort faces a high probability of failure or the collection of unnecessary or worthless data. Phenicie and Lyons (1973) present a logical and complete approach to setting objectives; the approach is applicable to all fields of study.

(2) A good objective is a specific action or activity, not a goal or wish. It places bounds on the work to be done, excluding nonapplicable or unnecessary efforts. Wording of an objective should be clear, concise, and simple. An objective must be <u>realistic</u> and therefore <u>attainable</u>, and <u>measurable</u> to allow evaluation of results and development of conclusions.

(3) Because of different objectives and environmental circumstances, scopes of monitoring programs need to be carefully developed on a case-by-case basis and are rarely identical for different projects.

c. Controls.

(1) Monitoring program design should provide for adequate controls. Data on baseline conditions serve as a temporal reference, and reference site data serve as a spatial reference.

(2) A set of baseline data is required to measure change. By definition, baseline data must be collected prior to the construction, dredging, or other environmental disturbance of interest. Depending upon study objectives, these data may or may not need to be collected over a multiyear period to lessen the statistical impact of the variability in natural systems. The use of a "typical year" may not be a valid approach because "typical years" may not be definable. The changes that occur in a system may not occur in a single annual cycle but may require several years to detect. However, data collected over any given year may still be valuable compared to the collection over part of a year or no collection at all.

(3) Reference sites representative of without-project conditions should be included in the monitoring program if at all possible. The purpose of reference sites is to evaluate changes that occur through time but are not related to the project. Without reference sites it is often very difficult to establish that observed changes are project related, and a question may remain as to whether natural variability or other perturbations were responsible for observed changes. In some cases, it may be possible to control for other perturbations by establishing more than one reference site. Reference stations may also be used to ensure that changes which occur within some designated boundary around an activity remain restricted within that boundary. Stations

may be situated in such a way that those nearer the activity would be impacted if the boundary was exceeded.

d. Quantitative Data. If the study objectives call for scientifically and legally defensible conclusions, baseline monitoring and reference data should be quantitative and the experimental design such that hypotheses concerning change can be statistically tested. Quantitative data sufficient for application of statistical tests are often expensive to obtain, a fact which underlines the prerequisite for well-defined objectives and importance of careful selection of parameters for measurement.

e. Remedial Action. The monitoring program design should include consideration of potential remedial action either during or following construction. If a desirable change does not occur or if an undesirable change is detected, this information is of little value unless a remedy is provided. The only positive result would be the lesson learned if a remedy is not provided. Of course, should a predicted change not occur or an unexpected change be observed, it is an indication that the predictive procedure was not accurate. In many cases, environmental processes are complex, and their interactions sometimes are not well understood. In such a case, understanding of the processes and interactions can serve as a useful feedback mechanism indicating a need for more environmental data and a need to modify and improve the predictive procedure.

7-2. Data Collection. This section provides general guidance necessary to plan an environmental monitoring program that will meet stated objectives of the study design. The most critical aspect of data collection is selecting proper parameters to sample and measure in order to address identified problems.

a. Primary Consideration. The quality of the information obtained through the sampling process is dependent upon these factors: collecting representative samples, using appropriate sampling techniques, protecting the samples until they are analyzed (sample preservation and handling), accuracy and precision of analysis, and correct interpretation of results. Other factors impacting on the sampling process are time, cost, and equipment constraints, which will limit the amount of information that can be gathered. Under such conditions, careful tailoring of the monitoring program is required. It will often be necessary to focus on a single basic objective rather than dilute available effort on tangential questions such that none are completely resolved.

b. Representative Sampling. The purpose of collecting samples is to acquire the basis for adequate representation and definition of the cultural, physical, chemical, or biological characteristics of the project area environment. To do so requires that sampling be conducted or samples be taken in locations which are typical of ambient conditions found at the project site. Failure to obtain samples that are truly representative of a given location will result in inaccurate data and misinterpretations.

c. Sampling Site Selection and Location. The following factors should be considered in sampling site selection:

(1) Objectives of the study.

(2) Accessibility of the site.

(3) Physical characteristics such as tides (consider extremes in amplitude, duration, and velocity), currents (mixing processes), salinity (means and extremes), and presence of vegetation.

(4) Available personnel and facilities.

(5) Cost or funding limitations.

(6) Past history and past studies conducted at or near the site.

(7) Type sampling proposed (random, stratified, or systematic).

d. Number of Stations. If reference areas, control areas, or former study sites are to be sampled for comparative purposes, multiple stations should be sampled. Sample composition from these areas will also be variable and cannot be defined based on single samples. If habitats or cultural horizons to be sampled are known to be heterogeneous, then stations should be allocated to strata (area of uniformity, such as depth, substrate type, and vegetated versus unvegetated) in proportion to spatial coverage of each stratum (e.g., stratified sampling). Therefore, more stations would be required to monitor impacts in physically, ecologically, or culturally complex environments.

e. Number of samples.

(1) Guidance in this section is limited to general concepts. First, the greater the number of samples collected, the better the sampled parameters will be defined. Second, on the other hand, the greater the number, the larger the cost; hence some reasonable compromise must be defined. Third, the mean of a series of replicated measurements is generally a better estimate of actual site conditions than any individual measurement. Fourth, statistics generally require calculation of two characteristics, usually a mean and a standard deviation, because single measurements are inadequate to describe a sample. Fifth, the necessary number of samples is proportional to the source heterogeneity.

(2) Consideration of the above factors suggests that replicate samples should be collected at each station location and that a minimum of three replicates are required to calculate standard deviations. Beyond the replication at a single point, the factors listed above do not limit the number of samples needed since the number of samples depends on site-specific heterogeneity (distribution pattern) and the desired level of source definition (degree of precision). The total number of necessary samples is controlled by the type

of dispersion pattern displayed by the organisms or habitat units to be sampled (random, aggregated, uniform) (Figure 7-1) and the level of precision desired. Additional information regarding "number of samples" can be found in Elliott (1977), Green (1979), and Snedecor and Cochran (1967).

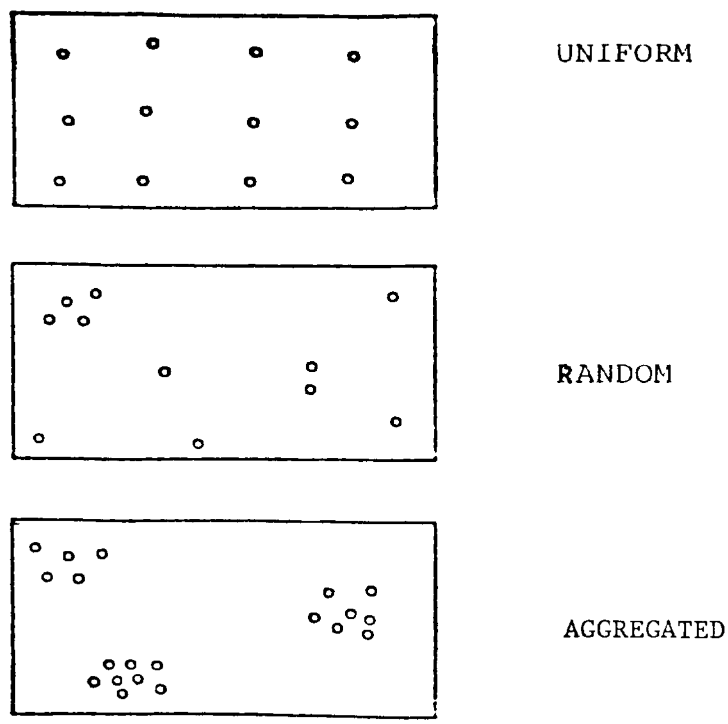

Figure 7-1. Three possible distribution patterns

(3) A rapid method for determining number of samples necessary when investigating a biological population is to calculate the cumulative mean of a few samples obtained in a pilot survey. A cumulative mean (or running average) consists of taking the average of samples 1 and 2; then of samples 1, 2, and 3 (first, second, and third, etc.); then of samples 1, 2, 3, and 4 (and so on), until all samples have been included. If the results are displayed (Figure 7-2), the plot of mean values will stabilize as more and more samples are included. In a population with a uniform distribution (when the variability is low), the mean stabilizes more quickly and in random populations less quickly. In the cluster distribution pattern, the cumulative mean value stabilizes most slowly and never stops fluctuating, although as can be seen in Figure 7-2, after about 15 samples the data begin to stabilize. In the illustrated examples, 8 to 10 samples would be minimally adequate to describe the randomly distributed population, whereas at least 15 to 20 samples would be required for the clustered population.

(4) A more sophisticated technique for estimating the number of samples is described by Green (1979). A preliminary or pilot survey is taken from the

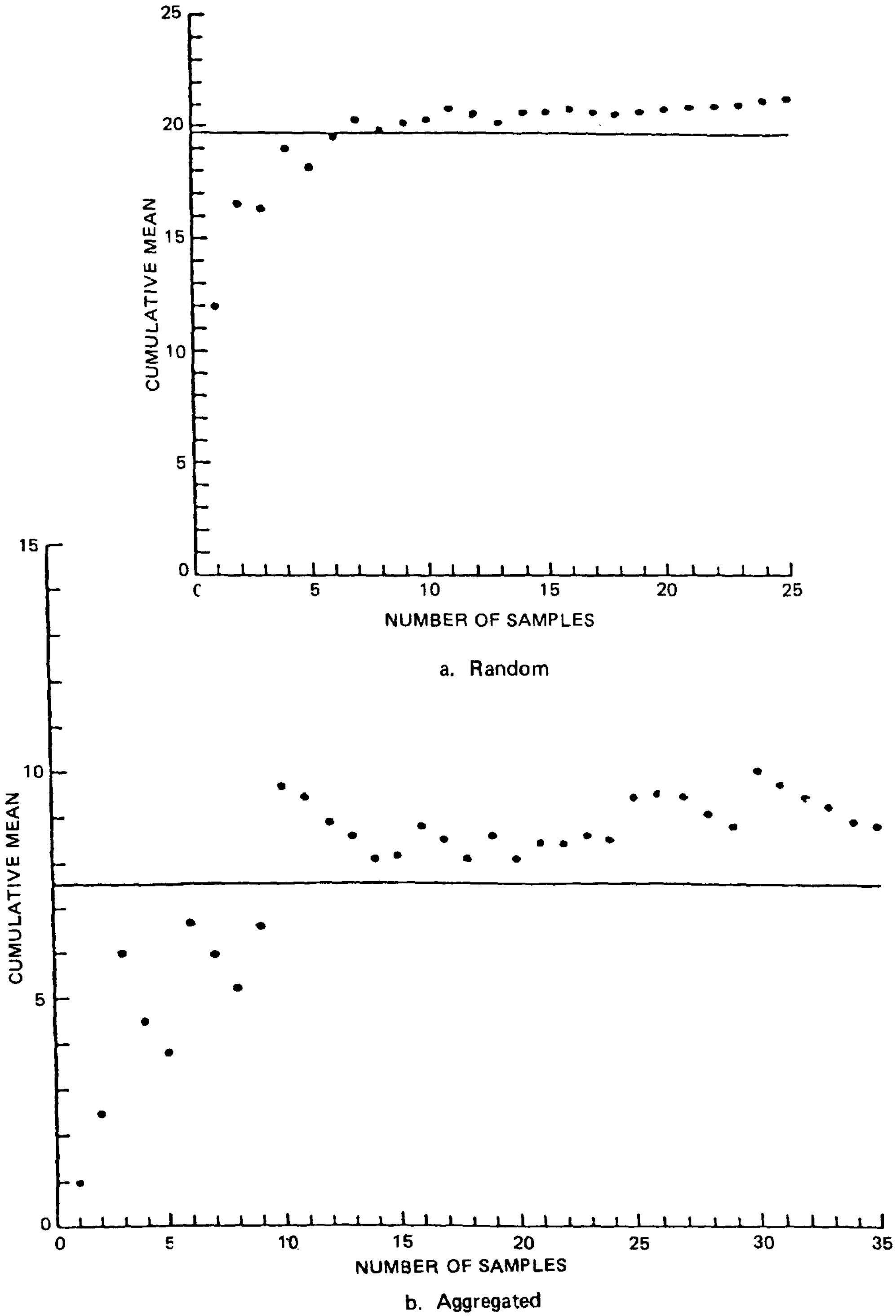

Figure 7-2. Cumulative means calculated for a random and a cluster distribution

population, and individual counts are made from each collection to calculate the sample mean and standard deviation. The following formula is then used:

$$\bar{X} \pm t_{1-(1/2)\alpha} \frac{s}{\sqrt{n}}$$

where $\bar{x}$ is the sample mean, t is the t statistic, " is the significance level, s is the standard deviation, and n is the number of samples. For example, assume that an investigator wishes to estimate the mean density of a species in a population within 10 percent of the actual number and with a l-in-20 chance of being wrong (0.95 confidence limits). The t value is unknown and is a function of n-1 degrees of freedom; however, for large sample sizes, t is a weak function of n and is approximately 2. If it can be estimated, then the formula can be solved for n . Refer to Green (1979) for an additional explanation.

(5) An additional factor which will serve to limit the number of samples is financial resources. For example, the number of samples upon which bioassays can be performed is determined by the ratio of available dollars and cost per sample:

$$\text{Maximum number of samples} = \frac{\text{Dollars available}}{\text{Cost per sample}}$$

This approach will provide one method of estimating the number of samples that can be collected and analyzed. However, should the calculated number of samples not be sufficient to establish an adequate sampling program (i.e., the number of samples is insufficient to allow replicate sampling at all locations indicated in para 7-2e) one of the following options will have to be considered. The first option is to reduce the replicate sampling at each station. This option will allow the distribution of a parameter within the project area to be determined, but variability at a single sampling station location could not be calculated. The second option is to maintain replicate sampling but reduce the number of sampling stations. This option will result in the project area being less well-defined, but sampling variability can be calculated. The consideration of these two options should be based on project-specific goals. If the first option is used (more stations but fewer replicates), the results will provide a better indication of distribution patterns in the project area, but it will be difficult to compare individual stations. If the second option is used (fewer stations but more replicates), the results will provide a better indication of variability at a given station and will improve comparison between sampling stations. However, the project area will be less well-defined. A third option is, of course, to increase the financial resources available for sample analysis. This option will increase the number of samples that can be collected and analyzed in order to establish an adequate sampling program.

(6) It is suggested that consideration be given to collecting samples (stations and numbers) in excess of that determined by the above process. The

samples do not have to be analyzed and may even be discarded later without analysis. Should sample analysis indicate abnormal results, it is easier and ultimately less expensive to analyze additional samples on hand rather than to remobilize a field crew. Also, the additional and potentially confounding variable of different sampling times is avoided with this approach.

f. Frequency of Sampling. Frequency of sampling will depend on the original objectives of the monitoring program, the availability of resources, and the size of the project. Seasonal fluctuations of physical and biological parameters may be or may not be suspected or known; therefore, seasonal sampling may be required. A sampling frequency of once per year may be sufficient for an annual maintenance project, unless there is a reason to believe otherwise (e.g., some major change in point sources or basin hydrology). If subtle impacts are to be detected, then long-term quarterly or more frequent sampling may be required to overcome the masking effect of wide seasonal and annual variation in the natural system.

g. Sampling Equipment. Sampling equipment should be selected based on the reliability and efficiency of the equipment and on the habitat to be sampled. Several types of water and sediment samplers used in the coastal zone are described in Table 7-1. The water column and sediments are frequently stratified vertically as well as horizontally, and this source of variability should be considered when choosing a method of sampling (i.e., grab versus corer). Additional techniques and equipment available to meet the particular needs of beach and rubble structure sampling are discussed in the following sections.

h. Sample Preservation.

(1) The importance of sample preservation between time of collection and time of analysis cannot be overemphasized particularly for water quality parameters. The purpose of collecting samples is to gain an understanding of the source (point of origin) of the sample; any changes in sample composition can invalidate conclusions regarding the source of the samples. Results based on deteriorated samples negate all efforts and costs expended to obtain reliable data.

(2) The most effective way to ensure a lack of sample deterioration is to follow instructions in the appropriate manuals or to analyze the samples immediately. However, this method may not be practical, and preservations may have to be used to assure the integrity of the samples until the analyses can be completed. In taking this approach, it must be remembered that complete stabilization is not possible and no single preservation technique is applicable to all parameters.

(3) Preservation is intended to retard biological action, hydrolysis, and/or oxidation of chemical constituents, and reduce volatility of constituents. Refrigeration in an airtight container is the only acceptable method to preserve sediments for bioassays. The elapsed time between sample collection and sample preservation must be kept to an absolute minimum.

TABLE 7-1

Sediment Sampling Equipment

Sampler	Weight	Remarks
Peterson	39-93 lb	Samples 144-in, area to depth of up to 12 in., depending on sediment texture
Shipek	150 lb	Samples 64-in. area to a depth of approximately 4 in.
Ekman	9 lb	Suitable only for very soft sediments
Ponar	45-60 lb	Samples 81-in. area to a depth of less than 12 in. Ineffective in hard clay
Reineck box	1,650 lb	Samples 91.3 in. to a depth of 17.6 in.

(4) The effects of transportation and preservation of sediment samples have not been fully evaluated. However, it is suggested that sediment samples should be sealed in airtight glass containers to preserve the anaerobic integrity of the sample and maintain the solid phase-liquid-phase equilibrium.

(5) Animals stored in the field should be preserved with a buffered 10 percent formalin-seawater solution stained with rose bengal. If stored for a period of time greater than three months, the benthic samples should be transferred to 70 percent isopropyl alcohol. After identification and enumeration, voucher specimens should be archived in 70 percent isopropyl alcohol. Reference collections should be maintained for reasonable postproject periods for quality control insurance (e.g., cross checking of taxonomic identifications should questions arise).

i. Sampling Beaches and the Nearshore Zone.

(1) Sampling methods.

(a) There have been few quantitative studies of the communities along high-energy coastal beaches because these areas are difficult and hazardous to sample. The Coastal Engineering Research Center (CERC) published a report that provided a standardized system for sampling macroinvertebrates on high-energy sand beaches (Hurme, Yancey, and Pullen 1979). This report suggests that samples on the upper beach be taken by excavating 0.1-square-meter quadrats with a trenching shovel and sieving the samples through a 0.5-millimeter mesh soil sieve. Compaction of the upper beach sediments can be measured in situ as a function of penetrability with a cone penetrometer. In the surf zone, a coring device generally provides a better and more consistent sample of the infauna (living in the sediments) than grabs or dredges. Beyond the surf zone, in deeper water, cores, grabs, and dredges may be used. Cores taken by a diver applying the quadrat techniques yield the most consistent quantitative samples (Figure 7-3). Trawls and beach seines are less quantitative, but they provide samples that are useful in interpreting biological changes in nektonic and epibenthic communities.

(b) When working in the surf, divers should use a transect line to stay on station (Figure 7-4); range markers on the beach are also helpful for keeping divers on station. Samples are generally collected along lines or transects perpendicular to the beach or parallel to the depth contours, depending upon objectives, and are stored in plastic bags, labeled, and preserved. Sorting of the animals from the sediments is done on the beach or in the laboratory. The animals preserved are later identified and counted.

(c) In clear water beyond the surf zone, diver observations and underwater photographs provide additional information on the epifauna (living on the surface of the bottom) that supplements core samples (Figure 7-5). Divers can observe and count attached reef animals, burrowing and reef fish which tend to be territorial, and pelagic fish.

(2) Sampling design. Sampling plans for a specific area depend on the nature and magnitude of the project, the use and purpose of the data, and the animals to be evaluated. The animals may be sessile or motile with populations that vary seasonally and distributions that are random or clustered. Refer to paragraph 7-2 for sampling design. In most cases, quantitative studies of the beach and nearshore will concentrate on the benthic community, especially the infauna. Epifauna and flora are usually not conspicuous on beaches. The following are general sampling design guidelines for the beach and nearshore zone.

(a) The infaunal sampling device should be reliable and accurate. It should ensure consistent substrate penetration, no loss of sample during retrieval, and minimal variation between sample sizes. Refer to Table 7-1 for typical benthic sampling devices.

(b) Sieve size for processing benthic (infauna) animals should be selected to ensure complete retention of macrofauna (Reish 1959, Hurme, Yancey, and Pullen 1979). By convention, a 0.5-millimeter mesh sieve is recommended for quantitative macrobenthic collections.

Figure 7-3. Core sampling at sandy-bottom stations

Figure 7-4. Diver using transect line in the surf

Figure 7-5. Quadrat sampling of epibiota at reef stations

(c) The number and the locations of stations should be chosen carefully before the project begins. Addition and deletion of stations should be avoided as much as possible. The number of stations should be adequate to address spatial variability of the infauna.

(d) Replications should be adequate to account for variability within station fauna and to collect the majority of the species inhabiting the study site. Refer to paragraph 7-2e on replicate sampling.

(e) There should be a sufficient temporal frequency of sampling to address seasonal variations in the physical and biological parameters.

(f) Sampling methods for "pre," "during," and "post" construction should be consistent and comparable.

(g) Because taxonomic identification is one of the costliest exercises in a monitoring program, level of identification of animals should be no greater than required by the stated objectives.

(h) Consistency in all procedures (sampling methods, sample processing, sample preservation, and sample analysis) should be maintained.

(3) Manpower requirements. Manpower estimated for collecting, processing, and analyzing benthic data varies depending on the location of sampling, site conditions and areal extent, number and type samples to be taken, the size of animals collected (macrobenthos or meiobenthos), and the level of taxonomic identification. As a general rule, project time for an assessment can be prorated as follows: field time - 10 to 25 percent; sample processing - 50 to 75 percent; data analysis - 5 to 10 percent; and preparation of an assessment document - 10 to 20 percent. Picking (separating benthos from sediments and debris) and sorting macrobenthic samples generally takes 1 to 4 hours per sample depending on whether or not the sediment is fine or coarse and whether the benthos are rare or abundant. Processing time, which includes taxonomic identification, counting, and weighing varies from 1 to 4 hours for beach samples with 25 to 75 species and 6 to 10 hours for nearshore samples with 200 to 300 species.

j. Sampling rubble structures. Although they provide excellent habitat for many fishes and shellfishes, rubble structures present difficulties in assessing these resources. The exposed armor layer of rubble structures creates an extremely rough and irregular surface such that obtaining biological samples of standardized volume, surface area, or other unit of habitat measure becomes a distinct problem. Specific biological sampling methods of potential application to rubble structure assessment are recommended below.

(1) Sampling epibenthic communities.

(a) Line transects. Van Dolah et al. (1984) used the following procedures to estimate the percent coverage of sessile biota on jetties at Murrells Inlet, South Carolina. Their methodology was adapted from line transect techniques described by Loya and Slobodkin (1971), Porter (1972a-b), and Loya (1972, 1978). A clear plastic strip with 15 inscribed marks at 2.5-centimeter intervals along its edge is placed against the rock surface. All organisms found directly under each mark (point) are identified and recorded. To accommodate the patchy distribution of many organisms on the same rock as related to the rock's orientation, assessments are made on each of the seaward, landward, outer, inner, and top surfaces of structure quarrystone at a station. The transect strip is always positioned horizontally on sloping or vertical rock faces. Ideally, the strip should be placed randomly upon each rock face rather than selecting areas of high-organism density. Nonrandom placement would introduce bias into the sampling. If more than one species is present under a point, all are recorded. At each station on the structure, samples are taken at predetermined elevations, including subtidal, intertidal, and supratidal levels. Percent cover estimates are then calculated based on the percentage of points each species occupied at a level or at a station. Because this procedure may result in estimates of total biota coverage of over 100 percent (more than one species can contribute to coverage at any given point), total biota coverage is adjusted by subtracting the estimated percent of unoccupied space from 100. For in situ observations, individual rocks can often be removed from the appropriate depth and brought to the surface for examination. Organisms unidentifiable in the field should be preserved and taken to the laboratory for identification.

(b) Scrape sampling. Manny et al. (1985) documented periphyton colonization of a rubble-mound jetty in Lake Erie. Samples were obtained with a bottle-brush sampler as described by Douglass (1958). Each sample covered 12.56 square centimeters (5.0 square inches) of rock surface. At a given station replicate samples can be taken and dedicated to separate analyses such as biomass estimation, taxonomic identification, and chlorophyll content determination.

(c) Quadrat sampling. Johnson and Dewit (1978) used randomly placed quadrats to characterize the biomass and densities of macrobenthic species assemblages on a rubble-mound island at Punta Gorda, California. Samples from subtidal and lower intertidal elevations were taken by using a 0.25-square meter (10.0-square-inch) quadrat, whereas samples in the upper intertidal zone were taken with duplicate 0.1-square-meter (40.0-square-inch) quadrats. Numbers drawn from a random numbers table, used as vertical and horizontal distances from fixed points on the structure, determined the location of each sample. Divers measured the specific distances along a steel tape measure, then dropped the quadrat behind them in order to minimize sampling bias in placement. To arrive at estimates of density, numbers of percent coverage (estimated visually) were recorded for each species in each quadrat. All detachable biota were removed and placed in labeled plastic bags for weighing in the laboratory. Subsamples of encrusting biota were scraped off rock surfaces with a steel chisel and hammer, then collected with a slurp gun (suction apparatus consisting of a plastic tube plunger system) fitted with a collecting chamber lined with plankton netting. Contents of the chamber were then processed with the biomass samples. Quadrant sampling can be adapted to other habitat types, including coral reefs, seagrass beds, and epibenthic communities that may occur in project areas.

(d) Suction samples. Motile epifauna can be sampled with devices such as slurp guns (Van Dolah et al. 1984) and pumps (Manny et al. 1985). Replicate or pooled samples can be taken with slurp guns by standardizing the number of pulls of the plunger rod. A flexible gasket around the opening of the slurp gun barrel can improve the fit of the device when placed against an uneven rock surface. Holes drilled in the base of the barrel and covered with fine mesh netting allow water to enter as the plunger is pulled, creating suction through venturi action. The volume of water and surface area of rock sampled can be calculated from the internal volume of the device and the barrel opening diameter, respectively. The pump sampler used by Manny et al. (1985) consisted of a gasoline-powered centrifugal pump fitted with a 5-centimeter-ID (inside diameter) hose. Incoming water passed through a screen head with 9-millimeter openings. Replicate three-minute pump samples were taken at each station, then filtered through standard mesh-size sieves. Samples were obtained by placing the intake hose in the interstices among the rock rubble. Thus, data were compared on a catch per unit effort basis because the absolute amount of surface area sampled was unknown.

(2) Sampling nekton. Assessment of fish and shellfish populations near rubble structures requires care to avoid the hazards of fouled nets and traps on the structures themselves.

(a) Nets and traps. If the bottom type is suitable, conventional trawling techniques can be used to sample demersal (bottom dwelling) fishes and shellfishes in the vicinity of rubble structures. Trawling would not, however, adequately sample nekton above the bottom and in the immediate area of the structures. Baited traps can be set directly on the rock surfaces but suffer from inherent selectivity in catch and susceptibility to loss during turbulent wave conditions or due to vandalism. Traps may be useful for assessment of specific target species (e.g., of commercial or recreational value) such as crabs or fishes intimately associated with the rubble substratum. In many cases, an appropriate gear type would be gill nets. Properly set, gill nets can be used to sample the water column immediately adjacent to a structure (generally set perpendicular to the axis of the structure) and can be set either high or low in the water column. Gill nets are less useful in deep water because the proportion of the water depth range sample of the net is less. Ideally, the same gear should be used at all sampling locations to avoid problems in comparing catch per unit effort data.

(b) Diver observations. Where water clarity conditions allow, underwater visual census techniques can be applied to assessments of rubble structure fish populations. A number of standard transect or point count techniques can be modified for use by swimmer-observers (Jones and Thompson 1978, Clarke 1986). Detailed studies of the fish fauna associated with rubble structures have been accomplished by divers (Hasting 1979, Stephens and Zerba 1981, Lindquist et al. 1985).

7-3. Habitat Assessment. In resource management decision making, questions that arise in the environmental review process can differ in specifics but have a fundamental theme: Will a project result in unacceptable changes in the functional "value" of the habitat involved? Two habitat assessment techniques and a series of marine and estuarine species profiles are available to assist in answering this important question.

a. Habitat Evaluation Procedures.

(1) Habitat-based evaluation procedures are designed to document the quality and quantity of habitat available for aquatic and terrestrial animals. These procedures can be used to compare the relative value of different areas at the same time (baseline studies) and/or the relative value of one area at different points in time (impact assessment), e.g., present conditions to future conditions. The effect of a project or environmental disturbance on animals can thus be quantified and displayed. One such procedure, the Habitat Evaluation Procedure (HEP), has not been applied frequently in estuarine! marine settings, although Cordes et al. (1985) provided one published example for Mobile Bay, Alabama. The limited application of HE? in coastal environments is primarily due to the small number of Habitat Suitability Index (HSI) models available for estuarine species (zero for marine species), and concerns over the sensitivity of HSI models in documenting impacts of Corps of Engineers activities on estuarine/marine species (Nelson 1987).

(2) HEP is computerized for use in habitat inventory, planning, management, impact assessment, and mitigation studies. The method consists of a basic accounting procedure that outputs quantitative information for each species evaluated. The information can pertain to all life stages of a species, to a specific life stage, or to groups of species. A HEP analysis includes the following (Refer to US Fish and Wildlife Service 1980b, Armour et al. 1984, and O'Neil 1985 for guidance and suggestions on conducting a HEP analysis.):

(a) Scoping. Scoping includes defining study objectives, delineating the boundary of the study area, and selecting aquatic evaluation species. The selection of evaluation species can be based on ecological importance, importance for human use (e.g., sport or commercial fishing), or other factors, including legal protection status.

(b) Development and use of Habitat Suitability Index models. An HSI model can be in one of several forms, including equations for standing crop or harvest, mathematical and nonmathematical mechanistic models that involve aggregations of variables that affect life requisites of a species, pattern recognition models, or narrative (word) models. The mechanistic model (Figure 7-6) is a commonly used model and requires development and use of Suitability Index (SI) curves (Figure 7-7). The tree diagram in Figure 7-6 illustrates the relationship of habitat variables and life requisites to the HSI for juvenile Atlantic croaker (Diaz and Onuf 1985). The value of each variable (V_n) is determined from a suitability curve as shown in Figure 7-7. HSI models published by the US Fish and Wildlife Service (Schamberger et al. 1982)

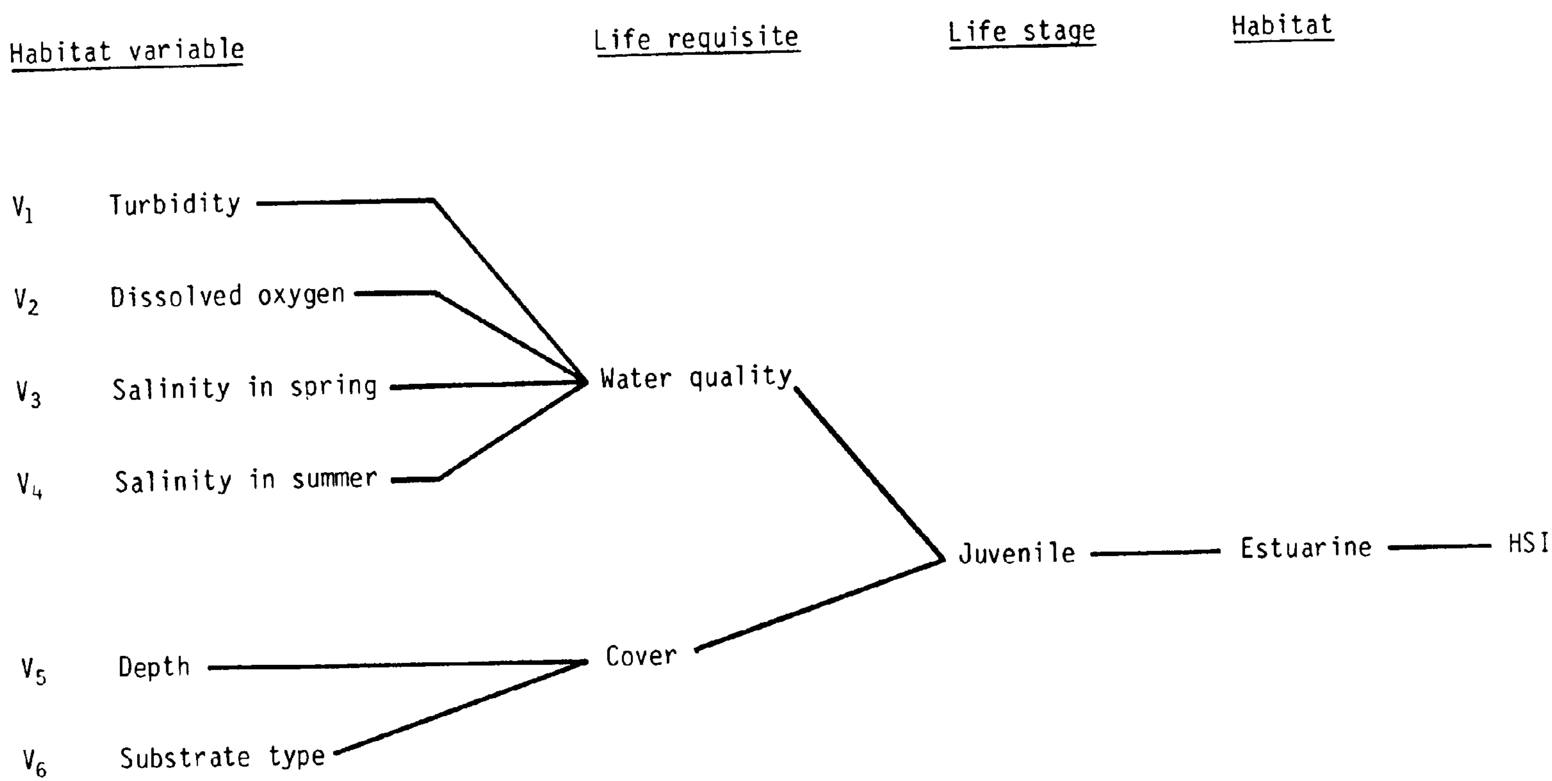

Figure 7-6. Example of a mechanistic Habitat Suitability Index model

V_6 Dominant substrate type:

1) >75% mud.

2) 25% to 75% mud.

3) >75% sand, shell, or other hard material.

4) Seagrass beds or mostly rock and shell; no soft material.

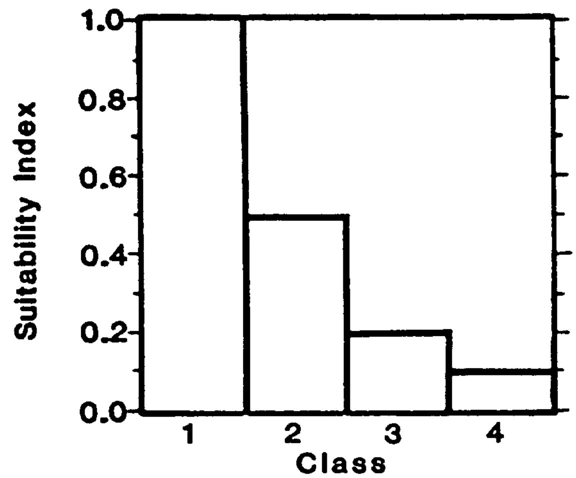

Figure 7-7. Suitability index curve for substrate type for juvenile Atlantic croakers Habitat Suitability Index model (Diaz and Onuf 1985)

should be evaluated by users to determine if they meet site-specific requirements. If the requirements are not met, the models can be modified or the user can develop new models for application. Guidance for developing HEP models is presented in "Standards for the Development of Habitat Suitability Index Models" (US Fish and Wildlife Service 1981). Availability of models is regularly updated in an instruction report by O'Neil (1985).

(c) Baseline assessment. Existing or baseline HU's are quantified within the study area for each evaluation species. HU's are derived by delineating the area of each habitat type for each evaluation species and then multiplying the area by its average HSI (HSI x area = HU). The number of HU's in the study area for an evaluation species is derived by summing the individual HU's for all habitat types and locations that provide habitat for the species for a particular life stage within the study site (Armour et al. 1984).

(d) Impact assessment. Target years are designated at specific points in time throughout the lifespan of the proposed project or study. A target year is defined as a specific year for which habitat conditions can be predicted and evaluated. Target years should be selected for points in time when rates of loss or gain in HSI, or area of available habitat, are predicted to change. The values for habitat variables for evaluation species must be predicted for each target year. Therefore, the planning agency must be able to predict habitat conditions for each alternative at each target year.

(e) Mitigation. Because HEP can be used to quantify losses resulting from proposed projects or construction activities, it can be used in mitigation studies. Habitat losses are determined, and the areas or measures designated for compensation are evaluated for various management alternatives to determine habitat gains. Partial or full compensation or enhancement to fish and wildlife habitat can be quantified. The analyses can be for in-kind compensation (one HU is provided for each HU lost for an evaluation species), equal replacement (a gain of one HU for a species to offset the loss of one HU for another, equally important, species), and relative trade-off.

(f) Decision on course of action. After the HEP analysis is completed, information is prepared for evaluation and use by decision makers and should include complete and clear documentation.

b. Benthic Resources Assessment Technique.

(1) Procedures have been developed at the US Army Waterways Experiment Station that use benthic characterization information to produce semiquantitative estimates of the potential trophic value of soft-bottom habitats. These procedures are called the Benthic Resources Assessment Technique (BRAT). As presently configured, BRAT can be applied under any circumstances in which the pre- or post-project fishery value of an unvegetated soft bottom is an important issue. Although developed primarily for application to subtidal estuarine and coastal marine systems, it may be feasible to apply the BRAT to evaluations on unvegetated intertidal or shallow subtidal bottoms as foraging habitat for wading birds and some waterfowl.

(2) In essence, BRAT estimates the amount of the benthos at a given site that is both vulnerable and available to target fish species that occur at the site. Here "vulnerable" and "available" are the key words. Different species of bottom-feeding fishes, by virtue of their particular morphological, physiological, and behavioral adaptations, can detect, capture, and ingest only a portion of the total benthos present. According to optimal foraging theory, fishes should feed on those food items which afford the greatest net nutritional/caloric benefit for the required energy expenditure for search, capture, and handling of prey. Thus, the optimal diet will depend on the abundance of the prey item, its size relative to the predator, its spatial and temporal distributions, and its defensive adaptations (camouflage, burrowing behavior, etc.). Bottom-feeding fishes will consume different prey at different locations and during different seasons, reflecting those vulnerable prey items that happen to be situated where they are available for capture. In the BRAT, vulnerability is taken to be a function of the depth of the prey’s location below the sediment-water interface. Both factors, vulnerability and availability, are estimated by examination of the diets of target predatory fishes.

(3) The overall BRAT approach is quite simple. Figure 7-8 depicts a flow chart of the major steps of the BRAT up to the point at which statistical and numerical analyses come into play. Benthos and fishes are collected simultaneously at the project site. Benthos are retrieved using a modified box-corer which enables the obtained sediment core to be partitioned into vertical depth intervals. The benthos are then removed and segregated according to their respective depth intervals. After separation from the sediments, the benthos from individual depth intervals are sorted into major taxonomic

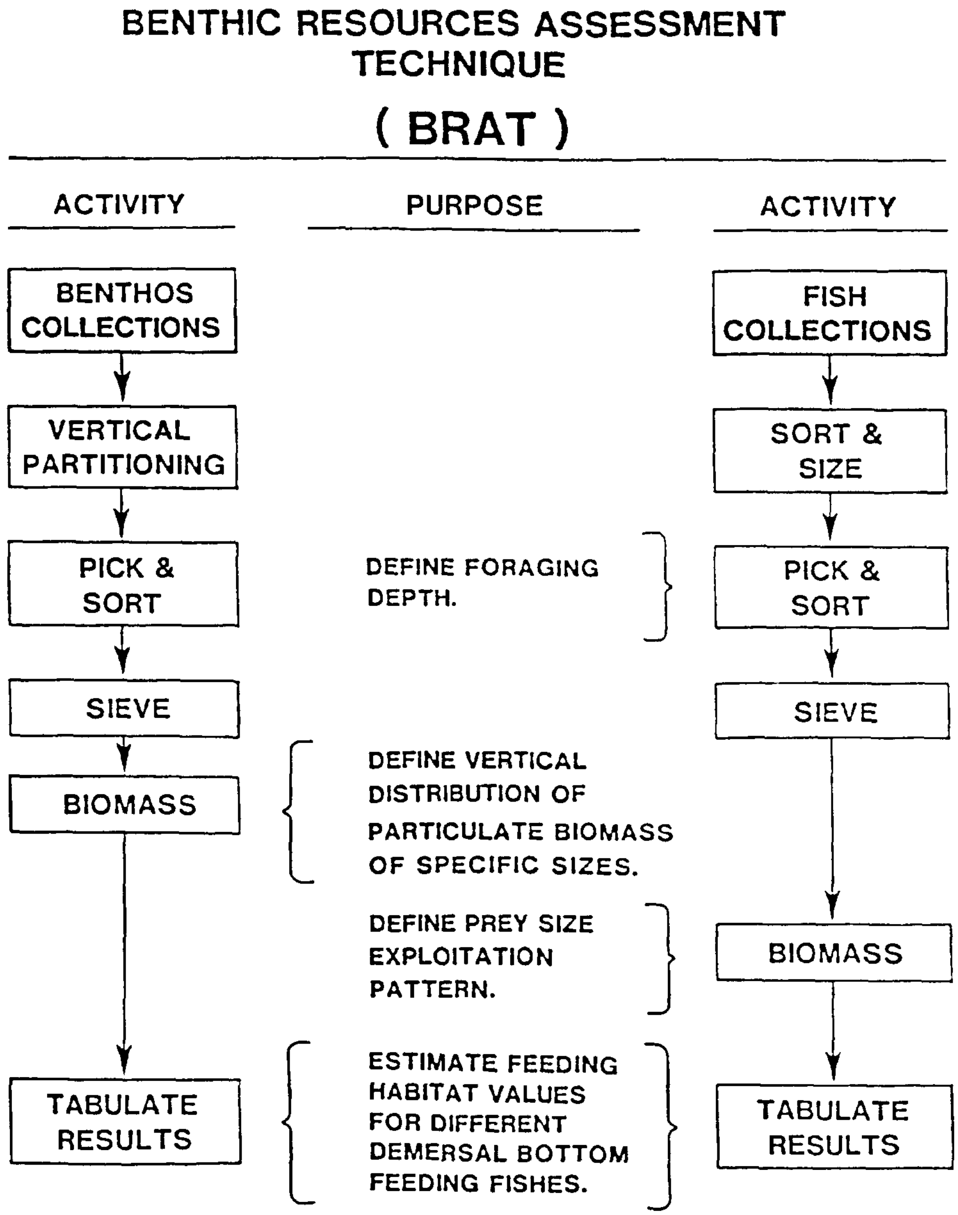

Figure 7-8. Benthic resources assessment technique (BRAT)

categories, then passed through a series of standardized mesh-size sieves. Each size fraction is then wet-weighed. At this point, the vertical distribution by size and weight of all potential food items has been established.

(4) Fishes that have been collected by conventional trawling methods are measured (standard length) and separated into size classes. Stomach content samples for fishes within each size class are pooled, then treated in a manner identical to the benthic samples. First, the food items are sorted into major taxonomic categories, then sieved into standardized size classes, and finally wet-weighed. Thus, there is a record of the size of prey items and the relative proportions of prey items utilized by bottom-feeding fishes in a project area at a given time. There is also a record of the locations of those utilized prey in the sediment column. What follows is simply a means of comparing the two records (actual food items eaten and food item size/depth distribution) to arrive at an estimate of the potential trophic support represented by a specified area of bottom habitat.

(5) Each size class of fish species will exhibit a particular prey exploitation pattern, i.e., its diet will be composed predominantly of prey items in a certain size range. This size range may be either narrow or broad. For projects at which there are multiple target fish species, and multiple size classes of each species, it will be necessary to use cluster analysis to assign each predator species size class to a prey exploitation pattern. Cluster analysis, also known as ordination, is a multivariate statistical technique which objectively sorts entities (in this case fish species size classes) into groups based on their attributes (sized-sorted prey items as used here). Cluster analysis is not an end in itself but rather an exploratory tool that assists in the recognition of patterns in large or complex data sets. The output in the BRAT is in the form of fish species size classes sorted into groups having similar prey exploitation patterns, or feeding strategies.

(6) Next, a second component of prey exploitation to be evaluated is the vertical foraging capability within the sediment column for each fish species size class. Qualitative examination of each food habitats sample provides evidence of the kinds of prey and their relative abundances. Comparison of this information with the vertical distribution patterns of these prey in the sediment column (derived from published reports or from the vertically partitioned box-core samples) gives an indication of the sediment depth to which a particular fish species or guild of species can forage. For example, hypothetical group A fish species size classes may eat prey less than 1 millimeter in size (vulnerable prey size) and be limited to foraging in the upper 5 centimeters of sediment (available foraging zone). The total amount of benthic biomass potentially exploitable by group A predators can be calculated as the cumulative biomass of all food items less than 1 millimeter in size for all sediment intervals down to 5 centimeters. Because the original box-core samples represented a standardized surface area of bottom habitat, an estimate of the total amount of food potentially available to group A predators in a project area can be extrapolated. By repeating this process for all bottom-feeding predator groups found in the project area, and taking the sum of their

exploitable prey biomasses, an estimate of the potential trophic support for all target fish species can be obtained. An example of BRAT data tabulation is presented in Table 7-2. In this example, the potential food value of the sampled bottom habitat was found to be 12.3 grams per square meter of vulnerable available biomass. The tabulation would be repeated for each benthic feeding predator group.

TABLE 7-2

An Example of a BRAT Data Tabulation

Benthic Community Analysis						
Prey Taxa	Vulnerable Size	Proportion of Biomass in Available Zone		Biomass/ Productivity		Potential Food Value
1	+	100%	×	10 g/m^2	=	10 g/m^2
2	-	0%	×	3.1 g/m^2	=	0 g/m^2
3	+	50%	×	1.4 g/m^2	=	0.7 g/m^2
o	o	o	o	o	o	o
o	o	o	o	o	o	o
o	o	o	o	o	o	o
n	+	70%	×	2.3 g/m^2	=	1.6 g/m^2
				Total food value = 12.3 g/m^2		

NOTE: The food value in grams per square meter (g/m^2) can be converted to units of energy to compute potential fish production or to a suitability index (actual/optimum) value for input to a HEP analysis.

The analysis would be conducted separately for each predator guild (guild = n species).

(7) The utility of the BRAT lies in the ability to provide meaningful information relevant to value decisions by the resource manager. The BRAT does not provide an assessment of the overall status of the habitat but can be viewed as an in-depth assessment of a single habitat variable, that of trophic support. As such it may potentially contribute semiquantitative input to habitat-based assessments such as the Habitat Evaluation Procedures.

c. Species Profiles. A series of 126 profiles on marine and estuarine animals are being prepared for seven United States coastal biogeographic regions (Appendix D). The profiles are designed to provide coastal managers, engineers, and biologists with a brief but comprehensive sketch of the biological characteristics and environmental and habitat requirements of coastal species. They will assist the planners in predicting how populations of coastal species may react to environmental modifications resulting from engineering projects. The profiles are jointly developed by the US Army Corps of Engineers and the US Fish and Wildlife Service and may be acquired by contacting the Coastal Ecology Group at the Waterways Experiment Station in Vicksburg, Mississippi.

7-4. Data Analysis, Interpretation, and Presentation.

a. Data Analysis Plan and Presentation. A preliminary idea of the data analysis and presentation techniques to be used should be formulated during the study design stage. Green (1979) has outlined principles important to planning successful study design and data analysis. Several techniques are readily available for data analysis and presentation.

(1) Qualitative analysis. Results of qualitative analyses are generally prose statements based on visual observations and perhaps a few measurements.

(2) Maps and graphical analysis. Patterns inherent in data can often be revealed by mapping or graphing the data. Maps are used to show two- and three-dimensional spatial patterns, whereas graphical approaches are most useful for showing temporal relationships or variations with a single dimension such as distance or depth. In general, variables can be divided into two types-continuous and discontinuous (or discrete)--and appropriate map and graphical techniques vary, depending on how variables are measured and distributed.

(a) Phenomena to be mapped may be distributed in a continuous or discrete manner. Discrete distributions are composed of individual elements that are countable or measurable (individual fish, species of fish, etc.), whereas with continuous distributions there are no recognizable individuals (dissolved oxygen concentration, turbidity, etc.). Symbols such as dots may be used to map discrete distributions to reveal patterns. Discrete data are often converted into densities by dividing counts of individuals (frequencies) by the areas of the spatial observation units. The results (animals per square meter, biomass per square meter, etc.) may be plotted on maps. Patterns are often enhanced by grouping all values into five or six classes and mapping each class with a separate tone or color. Data representing continuous distribution are usually plotted and contoured to reveal patterns.

(b) Graphic techniques specialized for certain disciplines or types of data are too numerous to describe. As with maps, however, graphic techniques vary with the type of data. Discrete data are often graphed as frequency histograms (or by graphs), with frequencies on the vertical axis and classes or categories on the horizontal axis. Continuous data are usually plotted as curves, with the spatial or temporal dimension on the X-axis. Logarithmic scales are often used when the data to be graphed vary over more than one order of magnitude. Patterns or trends in irregular curves may be more evident if the data are smoothed with a moving average or by fitting generalized mathematical functions to the plotted points. Schmid and Schmid (1979) provide a thorough review of graphs and charts. Tukey (1977) provides a discussion of graphical smoothing techniques. Tufte (1983) is an excellent source of ideas on clearly and accurately displaying quantitative data.

(c) More complex maps and graphs such as three-dimensional contour plots, trend surfaces, and perspective plots are also useful but more difficult to comprehend. Various mapping and geographical display options are available as part of most data management systems.

(3) Statistical analysis. Statistical analysis can be used to summarize or describe complex data bases. Statistics can also be used as a formal decision-making tool to decide whether measured temporal or spatial differences between samples are real or whether they may be the result of sampling variability. Commercially available data management systems have options for computing and displaying several types of statistics.

(a) Large amounts of data can be summarized by calculating statistics such as measures of central tendency (mean, median, and mode) and dispersion (standard deviation and range). Statistics can be used to compare sets of data to determine if differences exist among them and, if so, whether the differences are significant.

(b) Formulas are available for determining if observed differences between sample data sets are real, or if they may have occurred by chance because of insufficient sample size used in calculating the statistics. These techniques are called significance tests, and theories and formulas for their use are given in basic texts on statistics and experimental design. Users should be cautioned, however, that observed differences may be statistically significant and yet not be very meaningful. Special techniques have been developed or modified for analysis of biological data, particularly benthic biota data, e.g., Boesch (1977).

(c) Relationships among variables may be explored using correlation and regression analyses. For example, the relationship between the density of a certain benthic species and certain physical (water depth, temperature, sediment grain size, etc.) and chemical (dissolved oxygen, salinity, etc.) parameters might be explored using correlation and regression. Basic theory and formulas for correlation does not imply cause and effect relationships. Kenney (1982) discusses spurious self-correlations that result when two or more variables have a common term. The use of correlation and regression with several variables should be accompanied by a good understanding of the basic assumptions that must be met in order to use the techniques effectively. Mather (1976) presents a thorough discussion of the basic assumptions of multiple correlation and regression and of some of the mathematical and data constraints that influence results.

(d) Most data management systems contain programs for a variety of advanced statistical techniques. Pattern recognition techniques, such as cluster or character analysis, are powerful procedures for describing patterns and complex relationships when employed by individuals with sufficient training to understand the statistical and mathematical constraints to proper use of the technique.

b. Data Interpretation.

(1) Editing. Data checking and editing should precede analysis. Extreme errors may be detected by computer programs that check for boundary conditions and ensure that data values are within reasonable limits. Quality work requires human judgment. Simple computer plots of the raw data should be generated and examined for unreasonable values, extreme values, trends, and outliners. More detailed editing should include checking all or random samples of the computer data base values against data sheets from the lab or field.

(2) Analysis. The next step in data interpretation is to ensure that the assumptions on which the data analysis plan is based are still valid. New information or failure to collect all the data required in the original analysis plan may necessitate modification. Data analysis should then proceed according to plan, and a decision should be made to accept or reject the tested hypothesis. Following this step, an effort should be made to identify additional quantitative or qualitative conclusions that may be warranted, and additional hypotheses that may be tested using the data base. If resources permit, this additional analysis may be completed prior to formulation of final conclusions. Final conclusions should not be limited to acceptance or rejection of hypotheses but should extend to clear, verbal expression of the implications of the observed results. Decision makers who are not technical specialists may fail to grasp these implications unless they are clearly communicated.

(3) Maps and Graphs. When using maps and graphical techniques, one must be careful not to draw conclusions that depend on either interpolation between data points or extrapolation beyond the range of the data, unless such interpolation or extrapolation can be justified. Quantitative statements should not be based solely on map and graphical analysis. A choice of scales or coordinate axes that unduly exaggerate or minimize point scatter or differences should be avoided.